PCT/GB 2004 / 002846

The Patent Office

INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

REC'D 13 JUL 2004
WIPO PCT

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed Andrew Gersey

Dated 5 July 2004

BEST AVAILABLE COPY

Patents Form 1/77

Patents Act 1977
(Rule 16)

The Patent Office

05APR04 E886352-2 D02826
P01/7700 0.00-0407638.6 CHEQUE

THE PATENT OFFICE
SN
- 2 APR 2004
LONDON

The Patent Office

Cardiff Road
Newport
South Wales
NP10 8QQ

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

1.	Your reference	BP-09-0408
2.	Patent application number *(The Patent Office will fill in this part)*	0407638.6 2 APR 2004
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	The Morgan Crucible Company plc Morgan House Madeira Walk Windsor Berkshire SL4 1EP
	Patents ADP number *(if you know it)*	5808514002
	If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom
4.	Title of the invention	Flow Field Plate Geometries
5.	Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Phillips & Leigh 5 Pemberton Row London EC4A 3BA United Kingdom
	Patents ADP number *(if you know it)*	1289001

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	Priority: Complete this section if you are declaring priority from one or more earlier patent applications, filed in the last 12 months.			

		Number of earlier application	Date of filing *(day / month / year)*
7.	Divisionals, etc: Complete this section if this application is a divisional application or resulted from an entitlement dispute (see note f)		

8.	Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request? Answer 'Yes' if: a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body. Otherwise answer NO (See note d)	Yes

9. Accompanying documents: A patent application must include a description of the invention. Not counting duplicates, please enter the number of pages of each item accompanying this form:

Continuation sheets of this form	
Description	10
Claim*(s)*	1
Abstract	1
Drawing*(s)*	16 + 16 SN

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translation of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	1
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature(s)

Date
2[nd] April 2004

12. Name, daytime telephone and e-mail address, if any, number of person to contact in the United Kingdom

J.C. Boff
020 7822 8888

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered YES in part 8, a Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

f) *Part 7 should only be completed when a divisonal application is being made under section 15(4), or when an application is being made under section 8(3), 12(6) or 37(4) following an entilement dispute. By completing part 7 you are requesting that this application takes the same filing date as an earlier UK application. If you want the new application to have the same priority date(s) as the earlierUK apllication, you should also complete part 6 with the priority details.*

FLOW FIELD PLATE GEOMETRIES

This invention relates to fuel cells and electrolysers, and is particularly, although not exclusively, applicable to proton exchange membrane fuel cells and electrolysers.

Fuel cells are devices in which a fuel and an oxidant combine in a controlled manner to produce electricity directly. By directly producing electricity without intermediate combustion and generation steps, the electrical efficiency of a fuel cell is higher than using the fuel in a traditional generator. This much is widely known. A fuel cell sounds simple and desirable but many man-years of work have been expended in recent years attempting to produce practical fuel cell systems. An electrolyser is effectively a fuel cell in reverse, in which electricity is used to split water into hydrogen and oxygen.

Both fuel cells and electrolysers are likely to become important parts of the so-called "hydrogen economy". In the following, reference is made to fuel cells, but it should be remembered that the same principles apply to electrolysers. One type of fuel cell in commercial production is the so-called proton exchange membrane (PEM) fuel cell [sometimes called polymer electrolyte or solid polymer fuel cells (PEFCs)]. Such cells use hydrogen as a fuel and comprise an electrically insulating (but ionically conducting) polymer membrane having porous electrodes disposed on both faces. The membrane is typically a fluorosulphonate polymer and the electrodes typically comprise a noble metal catalyst dispersed on a carbonaceous powder substrate. This assembly of electrodes and membrane is often referred to as the membrane electrode assembly (MEA).

Hydrogen fuel is supplied to one electrode (the anode) where it is oxidised to release electrons to the anode and hydrogen ions to the electrolyte. Oxidant (typically air or oxygen) is supplied to the other electrode (the cathode) where electrons from the cathode combine with the oxygen and the hydrogen ions to produce water. A sub-class of proton exchange membrane fuel cell is the direct methanol fuel cell in which methanol is supplied as the fuel. This invention is intended to cover such fuel cells and indeed any other fuel cell.

In commercial PEM fuel cells many such membranes are stacked together separated by flow field plates (also referred to as bipolar plates or separators). The flow field plates are typically formed of metal or graphite to permit good transfer of electrons between the anode of one membrane and the cathode of the adjacent membrane. The flow field plates have a pattern of grooves on their surface to supply fluid (fuel or oxidant) and to remove water produced as a reaction product of the fuel cell.

To ensure that the fluids are dispersed evenly to their respective electrode surfaces a so-called gas diffusion layer (GDL) is placed between the electrode and the flow field plate. The gas diffusion layer is a porous material and typically comprises a carbon paper or cloth, often having a bonded layer of carbon powder on one face and coated with a hydrophobic material to promote water rejection.

An assembled body of flow field plates and membranes with associated fuel and oxidant supply manifolds is often referred to a fuel cell stack.

In WO02/065566 the applicants claimed a flow field plate having an assembly of progressively narrowing channels, which could link or be interdigitated with an opposed similar assembly of channels.

In co-pending PCT/GB2003/002621 the applicants have disclosed flow fields comprising geometries in which gas is delivered by gas delivery channels to a permeable wall, and is then transferred through the permeable wall to gas removal channels. Improved evenness of gas distribution was shown, but this application did not concern itself with water management issues.

In co-pending GB0316946.3, the applicants have disclosed a flow field plate (separator) for a fuel cell or electrolyser, comprising one or more branched primary gas delivery/removal channels feeding narrower secondary gas diffusion channels defined by an array of lands forming a network of interconnected gas diffusion channels therebetween.

The geometries described in these three applications have the common feature of providing multiple branched paths for gas across the flow field so as to provide a more uniform distribution of reactants across the flow field. The applicants have found that such geometries can cause problems in scaling however, in that if designs are simply scaled up to larger sizes, the diffusion paths become long and the widths of the feed channels can become too large.

Accordingly, the present invention provides a flow field plate (separator) for a fuel cell or electrolyser, comprising on at least one face a tiled array of flow field segments defining a reactant flow field. The flow field segments may be connected in parallel, in series, or in combinations thereof.

Further features of the invention are set out in the claims and as exemplified by the following description with reference to the drawings in which:-

Fig. 1	shows in plan a flow field plate design in accordance with the invention of PCT/GB2003/002621;
Fig. 2	shows an enlarged plan view of area A of Fig. 1;
Fig. 3	shows an alternative a flow field plate design in accordance with the invention of PCT/GB2003/002621;
Fig. 4	shows an enlarged plan view of area E of Fig. 3;
Fig. 5	shows in part a design for an array type flow field comprising a hexagonal array of channels;
Fig. 6	shows a further design in accordance with the invention of PCT/GB2003/002621;
Fig. 7	shows a design in accordance with GB 0316946.3;
Fig. 8	is an alternative channel arrangement for use in the design of Fig.5;
Fig. 9	shows a further design usable in conjunction with the present invention
Fig. 10	shows a flow field in accordance with the present invention;
Fig. 11	shows in enlarged fragmentary view a portion of the flow field of Fig. 10;
Fig. 12	shows an alternative embodiment of a parallel array of flow field segments according to the invention;

Fig. 13 shows a further embodiment of a parallel array of flow field segments according to the invention;

Fig. 14 shows a series connected array of flow field segments according to the invention;

Fig. 15 shows a further series connected array of flow field segments according to the invention;

and

Fig. 16 shows a series connected array of assemblies comprising parallel connected flow field segments according to the invention;

Figs. 1 and 2 show a flow field plate in accordance with the invention of PCT/GB2003/002621. A flow field plate 1 comprises manifolds and fastening holes 2 in a peripheral frame 18 that forms no part of the actual flow field. The plate also comprises a gas supply channel 3 to which a reactant gas is delivered by a manifold (not shown). Channel 3 communicates with gas delivery channels 4. Gas delivery channels 4 themselves connect to gas delivery sub-channels 5. In similar manner, a gas drain channel 6 connects with gas removal channels 7 and gas removal sub-channels 8.

The gas delivery channels and sub channels 4,5 and the gas removal channels and sub-channels 7,8 define between them a wall 9 having a plurality of diffusion channels 10 that offer a flow path from the gas delivery channels and sub channels 4,5 to the gas removal channels and sub-channels 7,8. In a typical case, for a small fuel cell having a plate size of ~10cm×10cm and a flow field working surface of ~6.5cm×6.5cm, the width of the gas delivery channels would be about 1.25mm, for the sub-channels about 0.5mm, and for the diffusion channels about 0.125mm.

The wall is convoluted on two scales.

On a first scale, it extends in a pleated or concertinaed manner from the gas supply channel 3 to the gas drain channel 6 and comprises wall segments 16 along each fold of the wall, and end wall segments 17 at each turn of the wall. The length of each fold of the wall is about 6cm in the example shown.

On a second scale, the walls between end wall segments 17 are themselves pleated or concertinaed to form the gas delivery and gas removal sub channels 5,8. The length of the gas delivery and gas removal sub-channels is about 2.5mm in the example shown.

This arrangement also ensures that the GDL is well supported by the flow field while ensuring that parts of the MEA lying above the land areas of the flow field are only a short distance from a channel (typically, for the arrangement shown, for the wall segments 16, within 0.5 mm or less of the closest channel and for end wall segment 17, within 1.25mm or less). This arrangement is readily scalable such that smaller wall segments 16 may be used giving still better access of gas to the area above the lands. Preferably no part of the flow field (and in particular of the wall segment 16) is more than 0.25mm from the closest gas delivery or diffusion channel.

To form both gas delivery and gas diffusion channels a technique such as sand blasting may be used in which a patterned template or resist is placed against the surface of a plate, the template or resist having a pattern corresponding to the desired channel geometry. Such a technique is described in WO01/04982, which is incorporated herein in its entirety as enabling the present invention. With this technique the plates may be formed from a graphite/resin composite or other non-porous electrically conductive material that does not react significantly with the reactants used.

Alternatively, the wall could be deposited onto a plate (e.g. by screen printing or the like) and in this case could be formed of a gas permeable material without the use of gas diffusion channels. It will be readily apparent to the person skilled in the art that there are many ways of producing a permeable wall.

Such methods can be used to make all of the flow fields described herein.

Figs. 3 and 4 show an alternative flow field plate design. A flow field plate comprises a central area 19 (for use with a surrounding frame 18 [not shown] as in Fig. 1). This has a gas supply channel 3 and a gas drain channel 6 and end wall segments 17 as in Fig. 1. The permeable walls are defined by an array of lands 20 forming a network of fine gas diffusion channels therebetween. Although circular lands are shown, the applicant has found that hexagonal or other lands offering a relatively constant channel width therebetween (e.g. polygonal lands) are preferred. A typical size for the lands is ~750μm ± 250μm with a spacing between lands of ~300μm ± 150μm.

Fig 5 shows in part a design for an array type flow field comprising a hexagonal array of channels connecting inlet channel 29 to outlet channel 30. The array comprises primary gas delivery/removal channels 31 defining a series of blocks 32 each themselves comprising a plurality of interconnected gas diffusion channels. In Fig. 5 the gas diffusion channels themselves form a hexagonal array, but Fig. 11 shows that other arrays of interconnected gas diffusion channels are feasible and contemplated. As with Figs. 3 and 4, although circular lands may be used, the applicant has found that hexagonal or other lands offering a relatively constant channel width therebetween are preferred. Again, a typical size for the lands is ~750µm ± 250µm with a spacing between lands of ~300µm ± 150µm.

Fig. 6 shows in a similar view a further design in accordance with the invention of PCT/GB2003/002621 in which the permeable wall comprises a series of gas diffusion channels extending at an angle to the gas delivery channels. Typical widths for the gas diffusion channels are ~400µm ± 250µm.

Fig. 7 shows in more detail a design, in which an inlet channel 21 connects to a branched gas delivery channel comprising a main stem 22 with branches 23. The branches 23 are interdigitated with branches 24 from the stems 25 of two branched gas removal channels feeding into an outlet channel 26. A permeable wall defined by lands separates the branched gas delivery channel from the branched gas removal channels.

Subsidiary channels 27 and 28 extend from the inlet channel 21and outlet channels 26 respectively to provide additional gas delivery/removal to regions where the branched gas delivery/removal channels do not extend.

In Fig. 9, another variant of flow field shows a fanned set of distribution tracks, 22, that may or may not include a taper for pressure equilisation. The example shown has linking secondary tracks 23 to aid the gas spreading. The alternative to this are the use of 'drain' tracks such as channels 27 and 28 shown in figure 7. . The areas 29 between the channels are formed from an array of lands defining a network of interconnected gas diffusion channels therebetween and diffusion of gas through these channels takes gas to the remainder of the flow field plate. Gas flow results in the direction A-B and gas departs the flow field through gas removal channels 30

In one example:-

- the main stems 22 taper from about 1.25 mm width at the inlet end to about 0.33mm at the end remote from the inlet
- the main stems vary in depth from about 1mm at the inlet end to about 0.5mm at the end remote from the inlet
- the branches 23 are about 0.45mm wide
- the areas 29 are formed from an array of diamond or lozenge shaped lands approximately 1.2mm in longest axis disposed in a hexagonal array, with the separation between lands being 0.4mm.

For larger plates and other less simple geometries such as high aspect ratios and other polygonal plates, a repeat unit or unit-cell approach can be used to tile the desired flow field. This is carried out in part to fit the shape but is also a effective way of yielding a more even gas flow and hence more even current generation across the flow field. Figure 10 and 11 show an example for a small plate having a flow field comprising four separate smaller flow fields based on the leaf type cell. The smaller flow fields are provided in pairs, with each pair provided with a common gas feed and to a drain channel at the perimeter of the flow field.

Again, the stem and branch structure could be of a number of variants that include the branched examples shown in figures 7, 10 and 11 and the fanned structure shown in figure 9. The cell can be centrally fed as shown in figure 10 and 11 or diagonally fed, as is figure 12. A serpentine flow field could even be used.

In more detail, in Figs. 10 and 11, a flow field plate 100 comprises four flow field segments101 each comprising a branched gas delivery channel 102, and a permeable region 103 surrounding the branched gas delivery channel.

Manifold 104, and primary gas delivery channel 105 and connecting gas delivery channels 106, feed the branched gas delivery channels 102. [The connecting gas delivery channels 106 in this example are branched, but separate channels to each flow field segment may be provided].

The permeable regions 103 are partially surrounded by gas removal channels 107. The gas removal channels 107 connect to connecting gas removal channels 108 which themselves connect to primary gas removal channel 109 and gas removal manifold 110.

Impermeable barriers 111 separate the primary gas delivery channel 105 and connecting gas delivery channels 106 from the connecting gas removal channels 108 and primary gas removal channel 109.

Additional lands are added to act as a number of ways. Lands 112 are provided as appropriate to resist ingress of the gas diffusion layer into the channels. This is normally only applicable where the width of the channel is such that a significant risk arises or where the gas diffusion layer is high deformable. The other action of the lands 112 in the central stem of the feed is to act as gas diversion devices where the gas flow is encouraged to split and this hence aids spread of the flow down the branches.

In effect, a common gas delivery system (primary gas delivery channel 105 and connecting gas delivery channels 106) feeds a plurality of flow field segments101 which themselves discharge into a common gas removal system (gas removal channels 107, connecting gas removal channels 108, and primary gas removal channel 109).

The arrangement of fuel cells resembles that of lungs. Whereas humans have only two, this arrangement permits many such flow fields to be ganged or tiled together to form a wider flow field.

There are a number of arrangements that can be formed from this concept, the two main classifications are the series and the parallel connected segmented cells. In the parallel connected arrangement each flow field segment is supplied in parallel and each discharges into a common drain. In the series arrangement, the flow draining from one flow field segment is used as the source for another flow field segment.

Figure 12 shows an example of a parallel-connected cell with a common feed where 114 is the inlet and 113 the outlet for the gas. Five smaller flow fields are provided comprising, as above, a main stem 22, secondary feed branches 23, and the drain branches 24 and 25.

Figure 13 shows a parallel design with direct feed to each of the cells, this example having four cells. Each inlet channel, 114 is divided by a land 120 to form individual channels 121 feeding the individual cells via a main stem, 22, that can be branched in a similar way to the single pattern designs. The separate parts of the inlet channel 114 can be of different cross-section so as to provide balanced flow within the separate segments. Again each segment or repeat is separated by a land strip 111 and the drain is separated from the feed by arrays of columns that act as permeable material.

In a similar way Fig. 14 shows a first variant of a series design whereby the inlet for a flow field segment of a flow field array is fed from the outlet of another flow field segment. The individual segments can be formed in any of the arrangements described above or even as conventional serpentine flow fields. The example shown is for a branched 'leaf' type feed, with main stem 22, secondary branches 23 and drain branches 24 separated by the permeable materials 103. The flow field segments are divided by lands 111, which preferably should be of a size large enough to separate the major gas flow between segments and sufficiently small to allow current generation at the membrane above the land area. These strips of repeated segments can be built into an array to cover the whole of the active area of the flow field plate as shown in Fig. 14. Here two rows of segments are fed independently in series so that the whole flow field can be considered as a parallel assembly of series connected flow fields.

Figure 15 shows another variant of the series design whereby the segments are separated in the same manner as described above using lands , 111, here the segments are hexagonal or of a shape that can be designed to tessellate with the adjacent segment. Each segment feeds into a drain channel and this is fed into a subsequent downstream segment. This refocusing of the gas flow into a collimated channel increases the gas velocity and aids water mixing into a single phase fluid to reduce the likelihood of condensation and track blockage. Again, this arrangement can be considered as being a parallel arrangement of series connected flow fields.

It is evident that an alternative arrangement would be to provide a serial assembly of parallel flow field – e.g. tiling several assemblies as shown in Fig. 12 across the flow field so that the drain 113 of one assembly becomes the source 114 of the adjacent assembly. Fig. 16 shows such an arrangement with flow being generally in the direction of the arrow.

More complex arrangements of parallel/serial architecture can readily be envisaged. The invention encompasses all arrangements in which there is a tiled array of flow field segments defining a reactant flow field.

CLAIMS

1. A flow field plate (separator) for a fuel cell or electrolyser, comprising on at least one face a tiled array of flow field segments defining a reactant flow field.

2. A flow field plate as claimed in Claim 1, in which the flow field segments are arranged in parallel.

3. A flow field plate as claimed in Claim 1, in which the flow field segments are arranged in series.

4. A flow field plate as claimed in Claim 1, in which the flow field segments are arranged as a parallel assembly of series connected flow field segments.

5. A flow field plate as claimed in Claim 1, in which the flow field segments are arranged as a series assembly of parallel connected flow field segments.

6. A flow field plate, as claimed in any preceding Claim, comprising one or more branched gas delivery/removal channels, and a permeable region surrounding the branched gas delivery/removal channels.

7. A flow field plate, as claimed in Claim 6, in which a common gas delivery system is arranged to feed the branched gas delivery/removal channels.

8. A flow field plate, as claimed in Claim 6 or Claim 7, in which a common gas removal system is arranged to accept discharge from the permeable region.

9. A flow field plate, as claimed in any one of Claims 1 to 8 , in which lands are provided to resist ingress of the gas diffusion layer into channels of the flow field.

10. A fuel cell comprising one or more flow field plates in accordance with any one of Claims 1 to 9.

Agent's Ref: BP-09-0408

ABSTRACT

A flow field plate (separator) for a fuel cell or electrolyser comprises on at least one face a tiled array of flow field segments defining a reactant flow field.

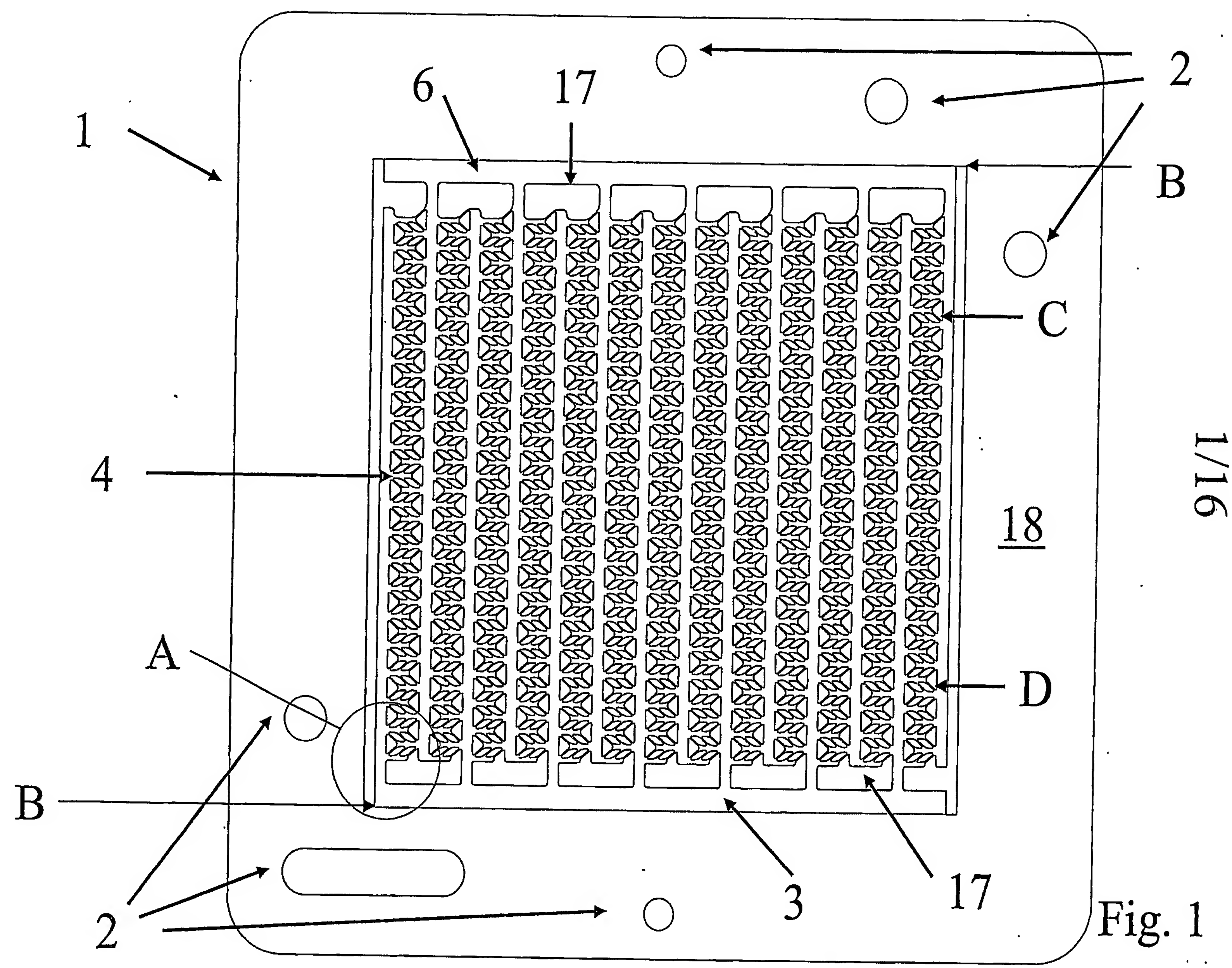


Fig. 1

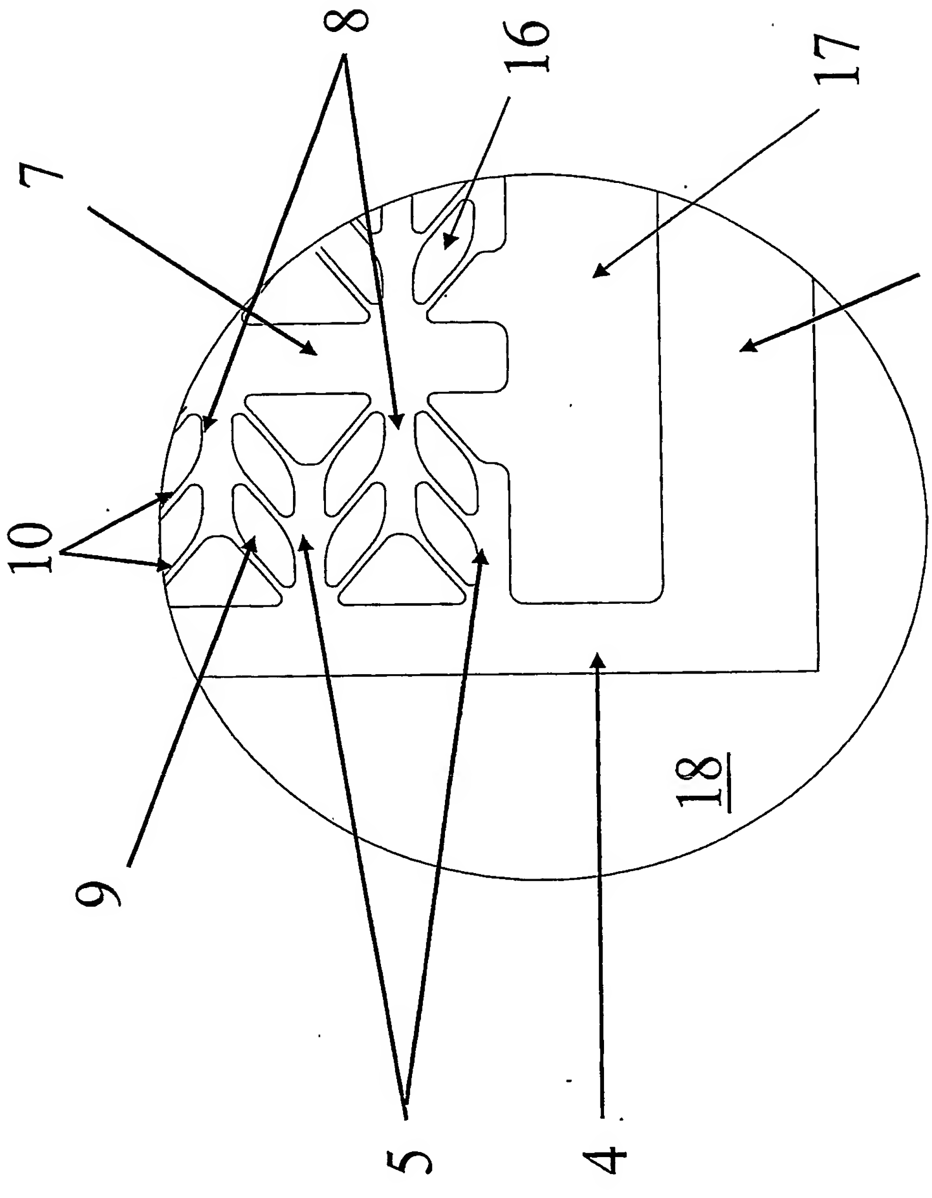
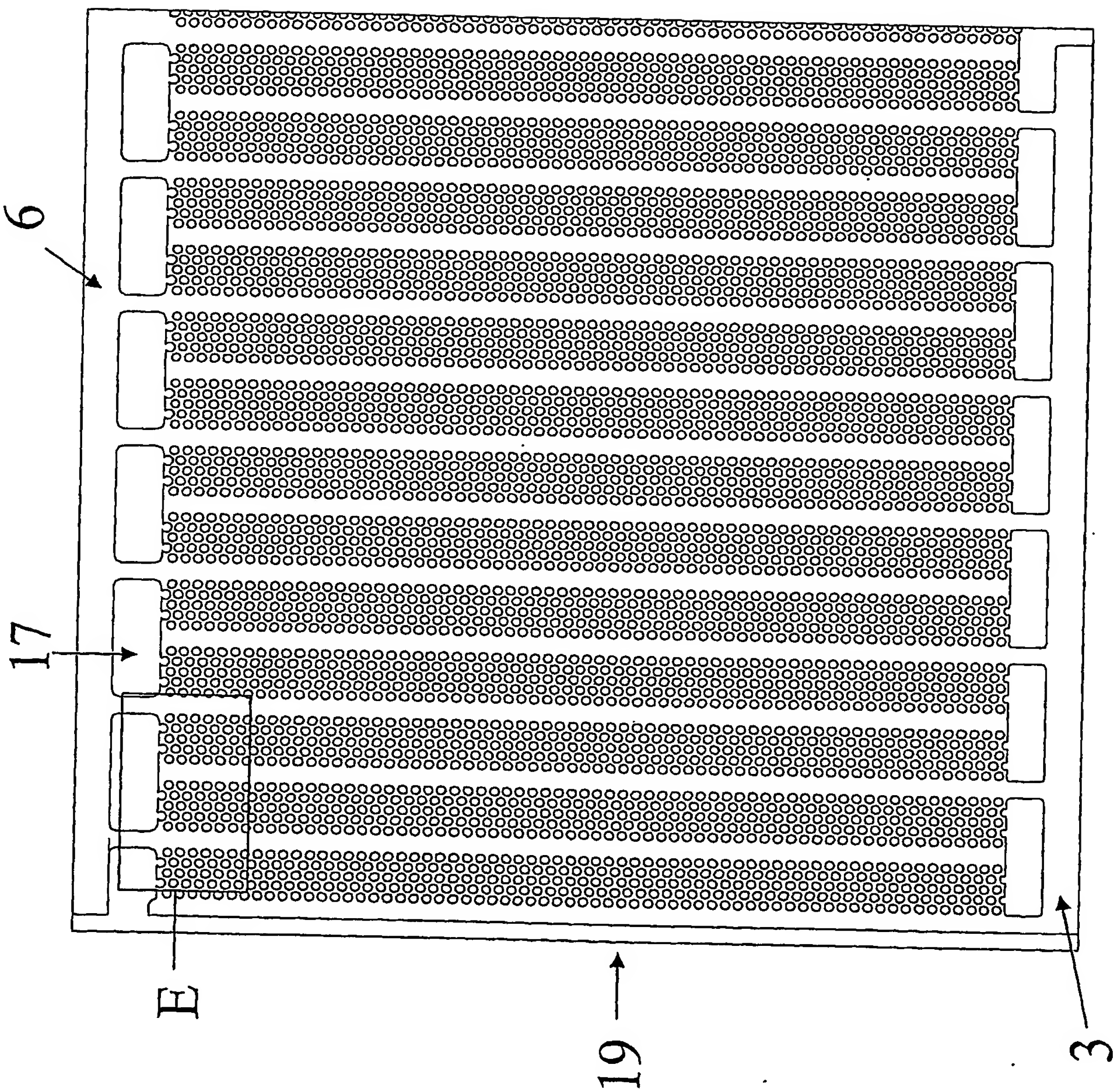


Fig. 2

Fig. 3



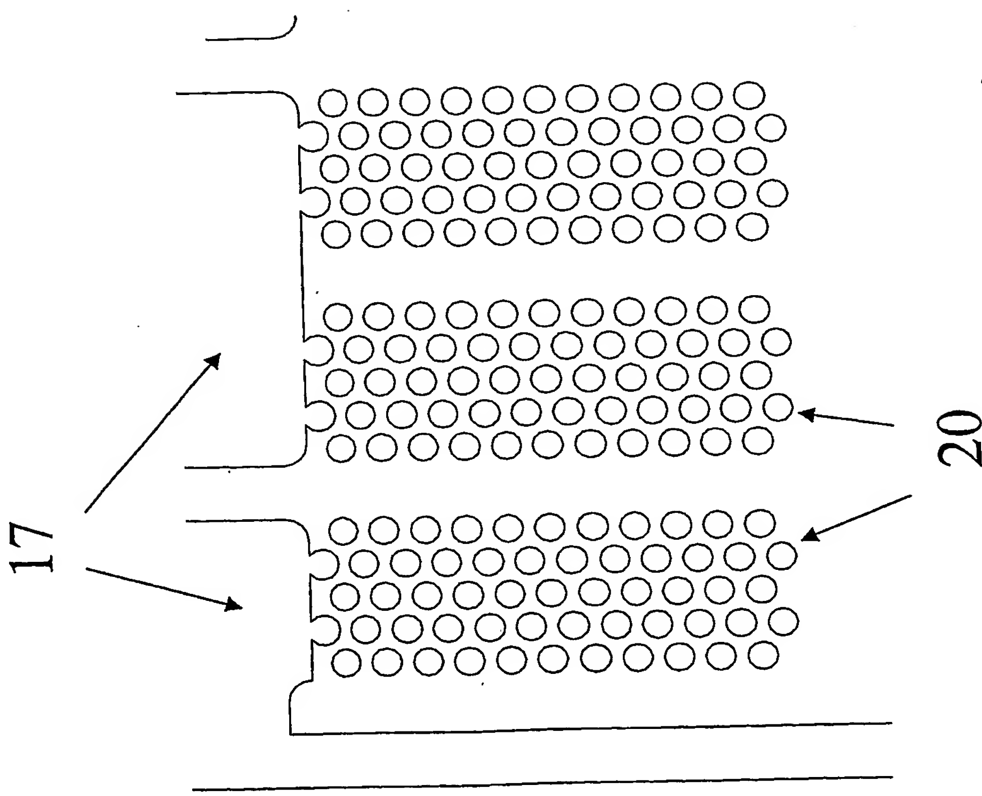


Fig. 4

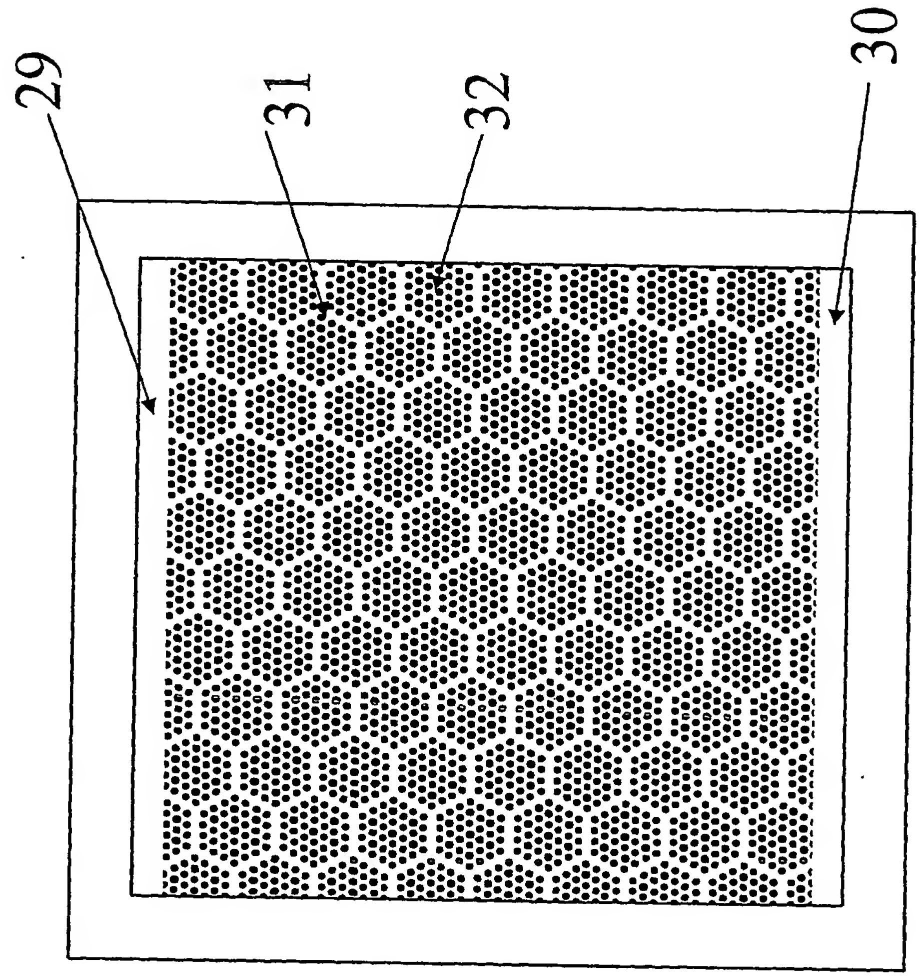


Fig. 5

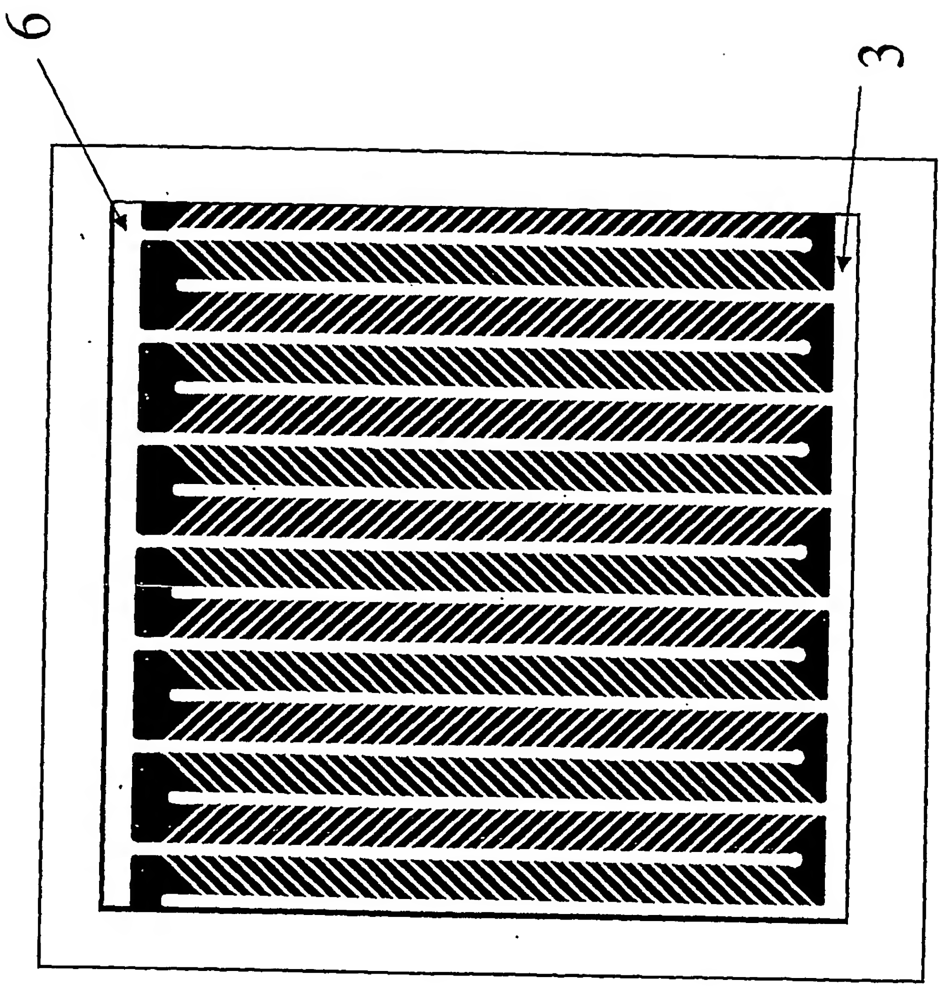


Fig. 6

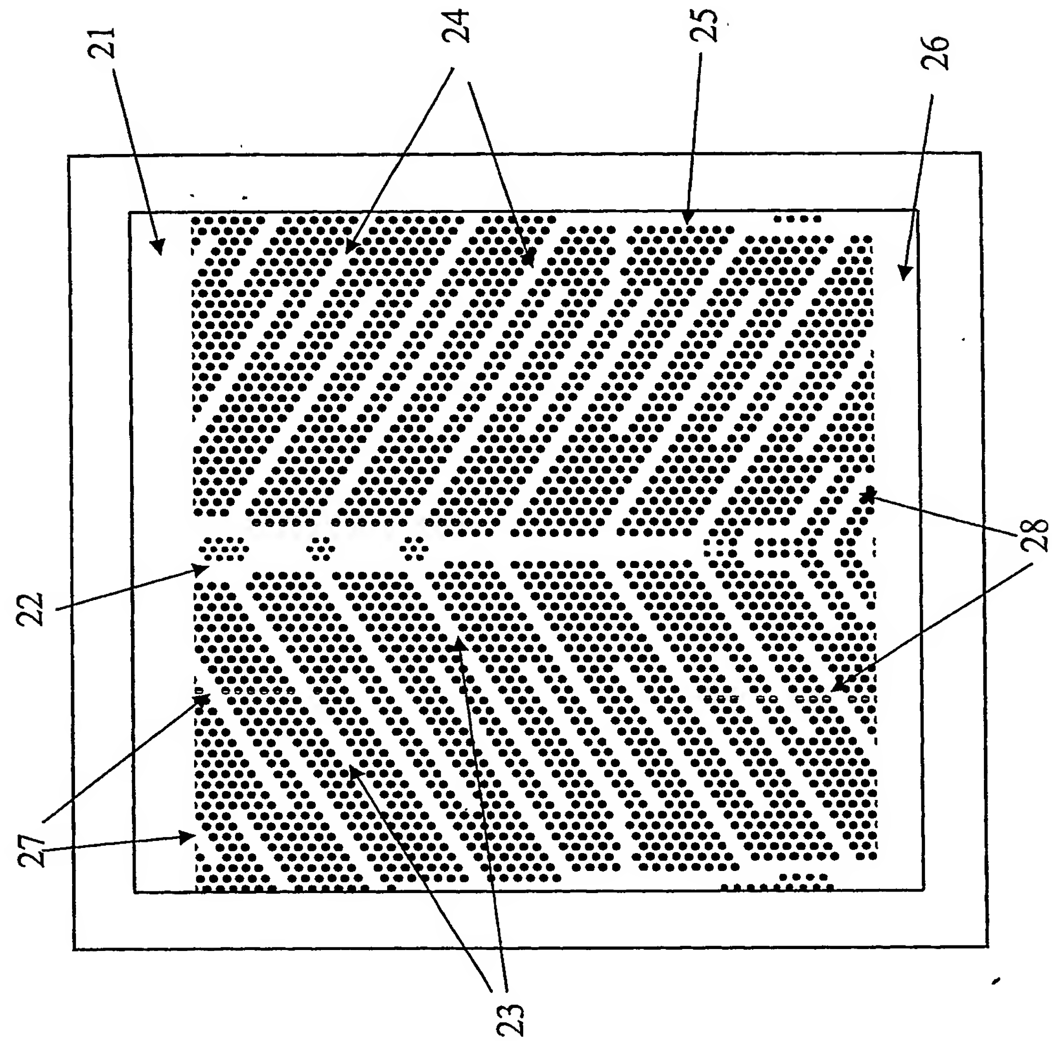


Fig. 7

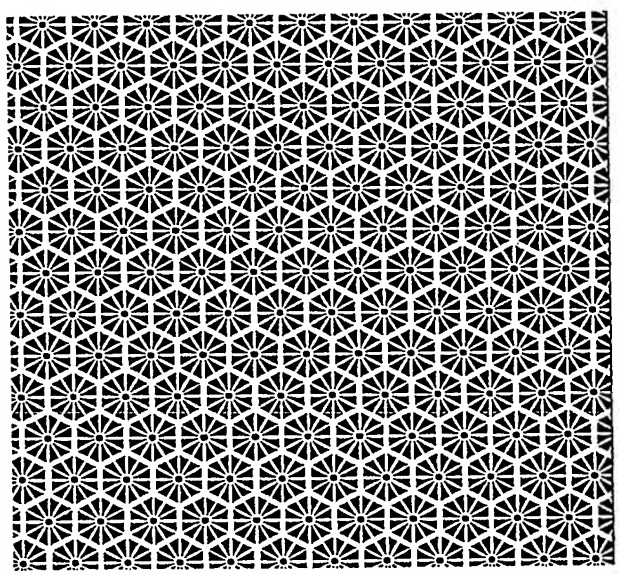
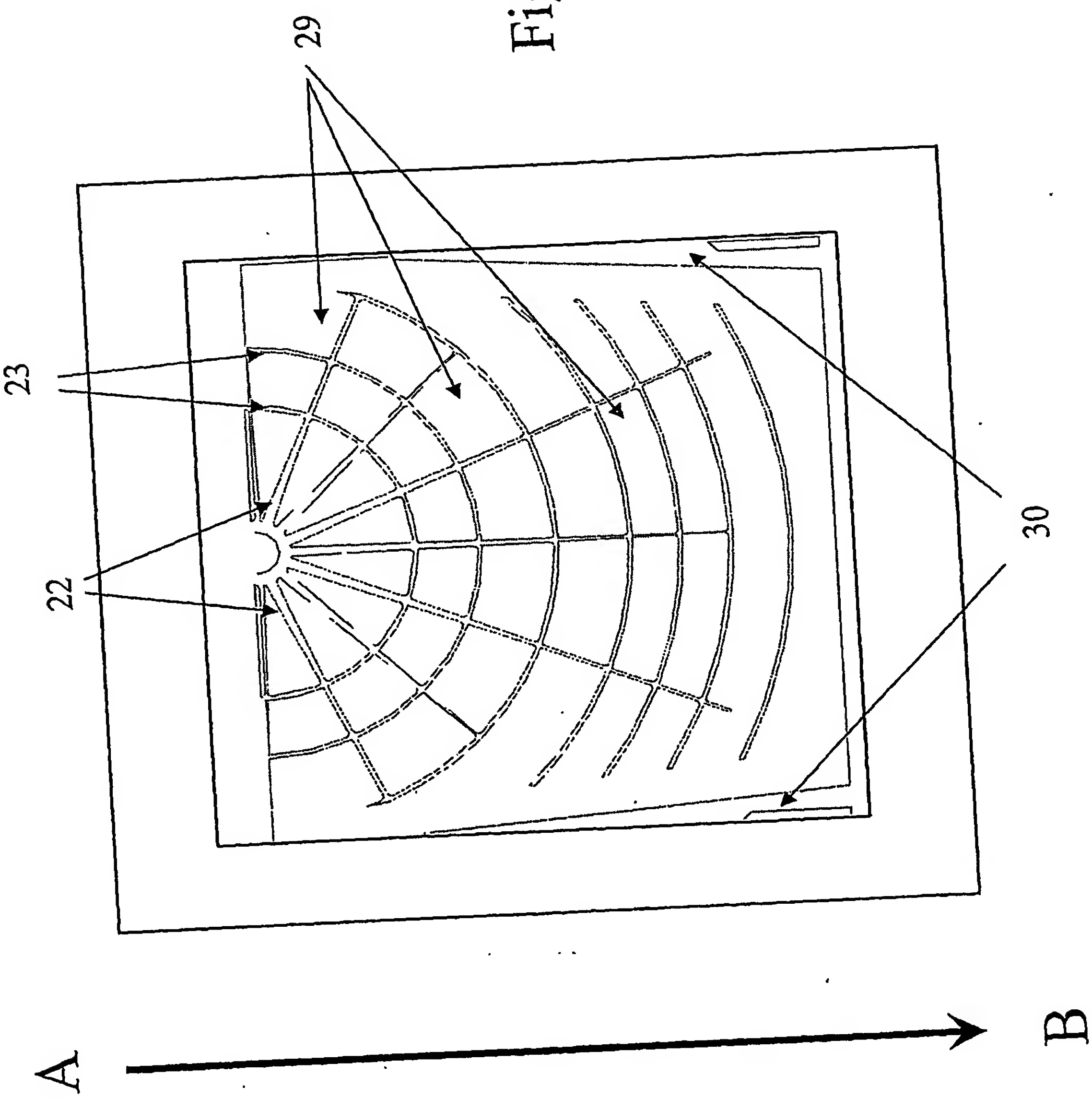


Fig. 8

Fig. 9



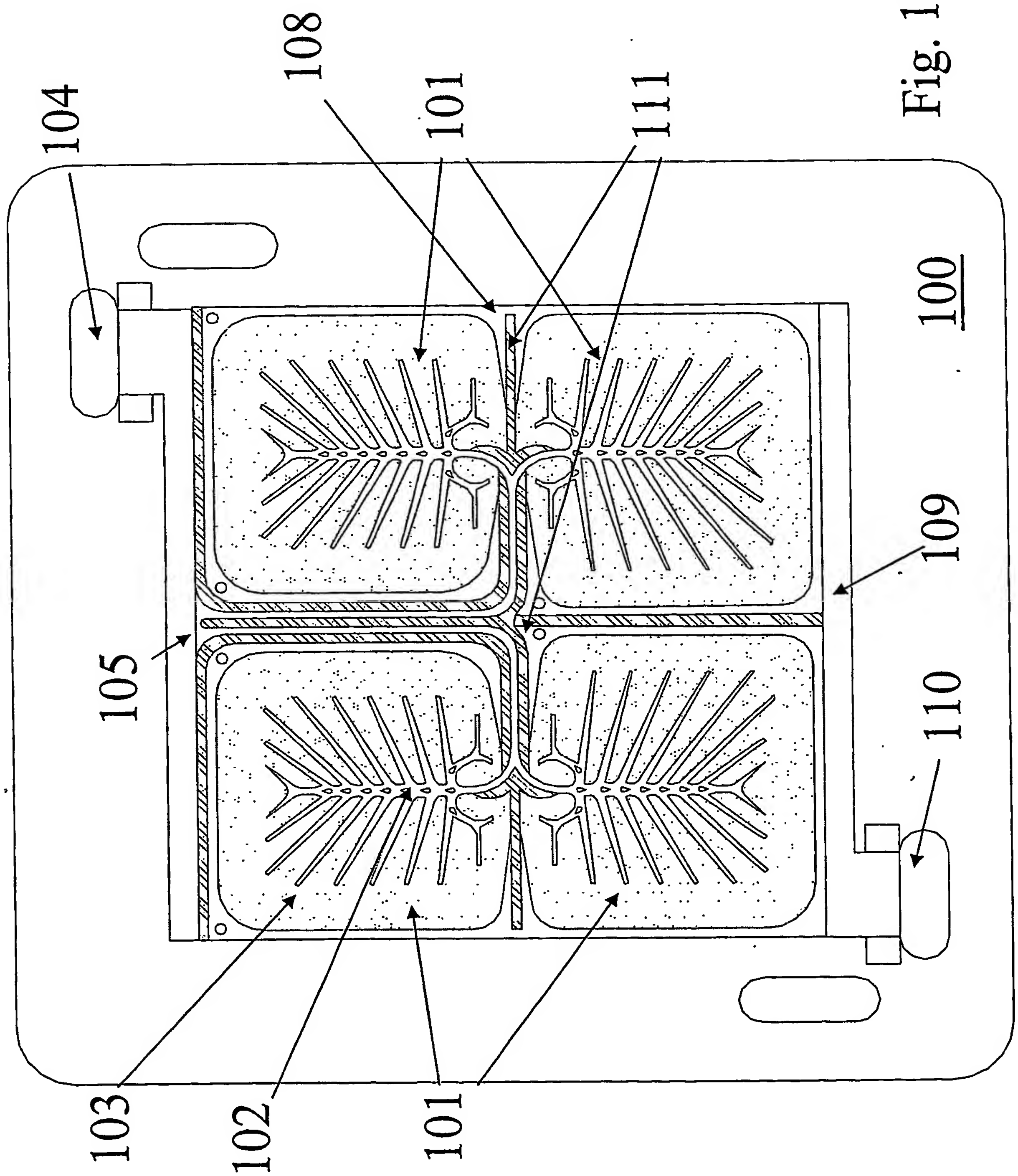


Fig. 10

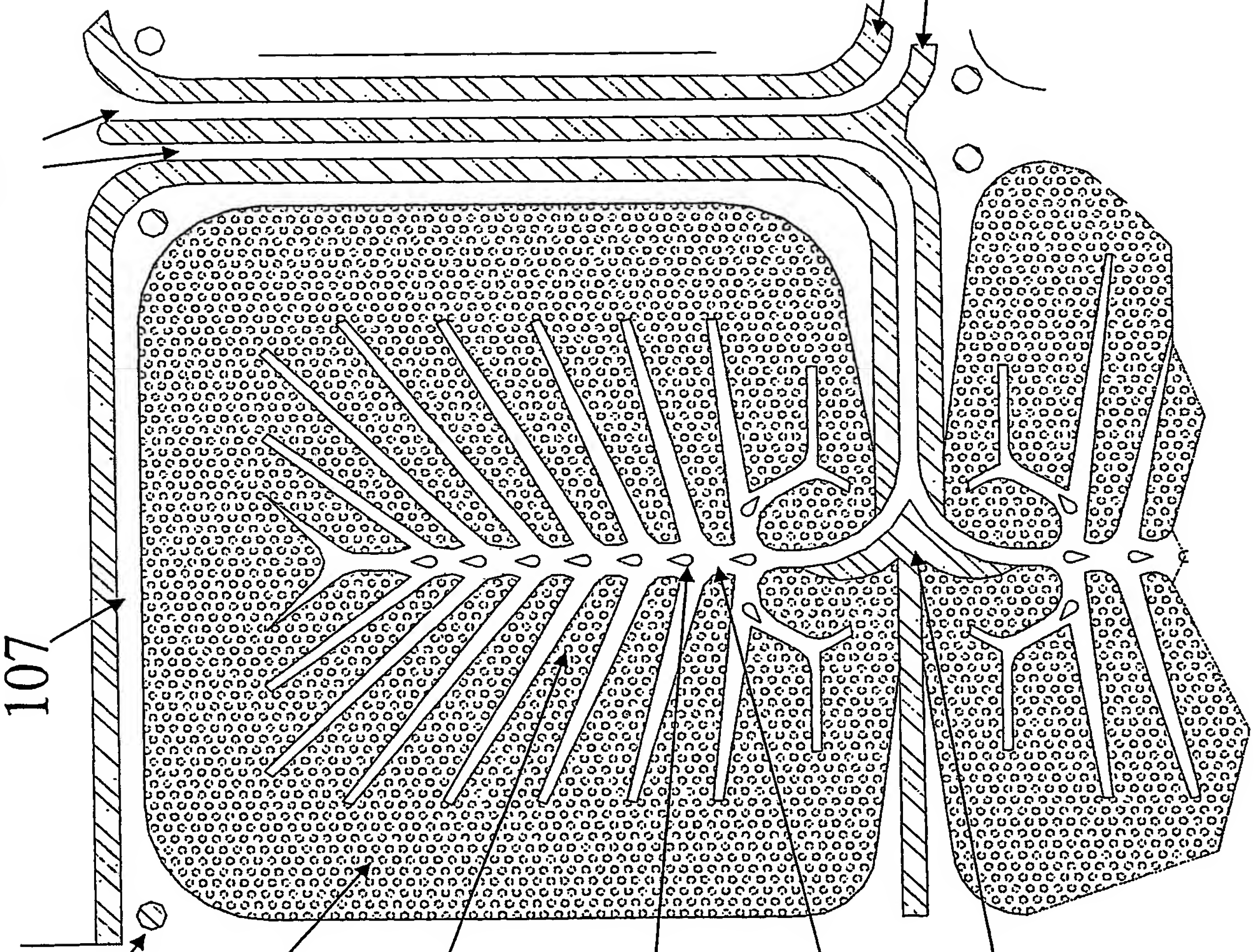


Fig. 11

Fig 12

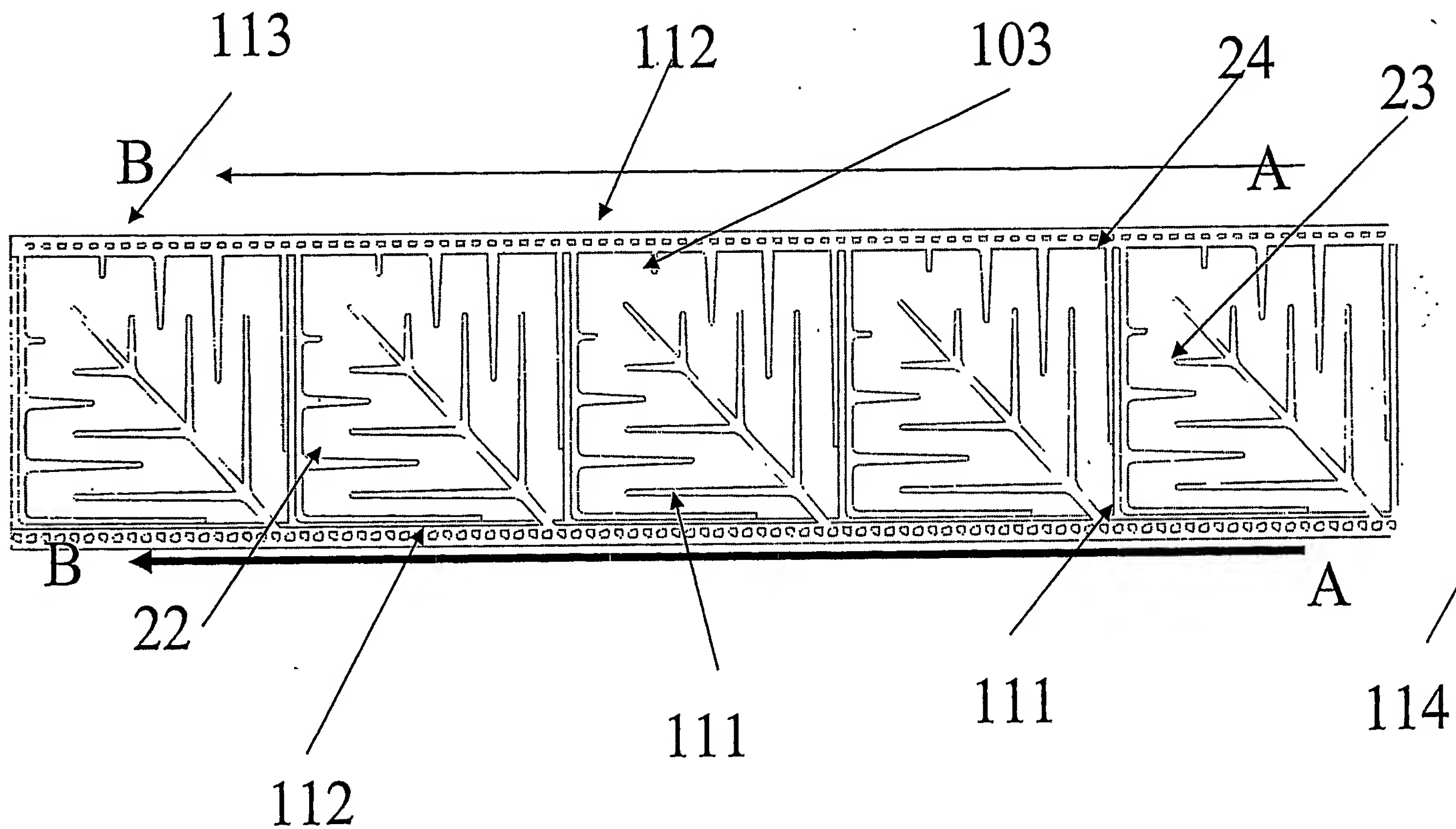
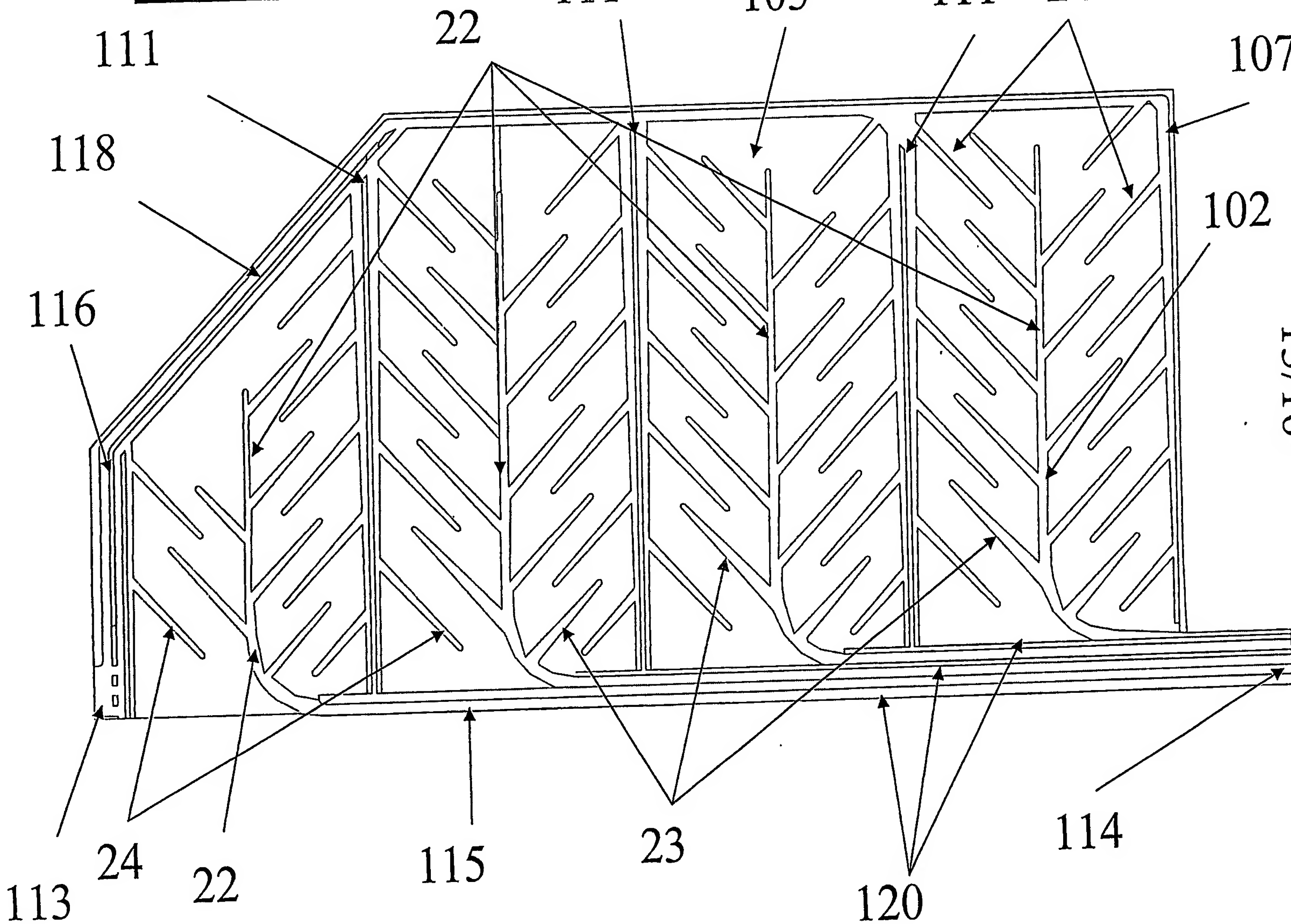


FIG 13



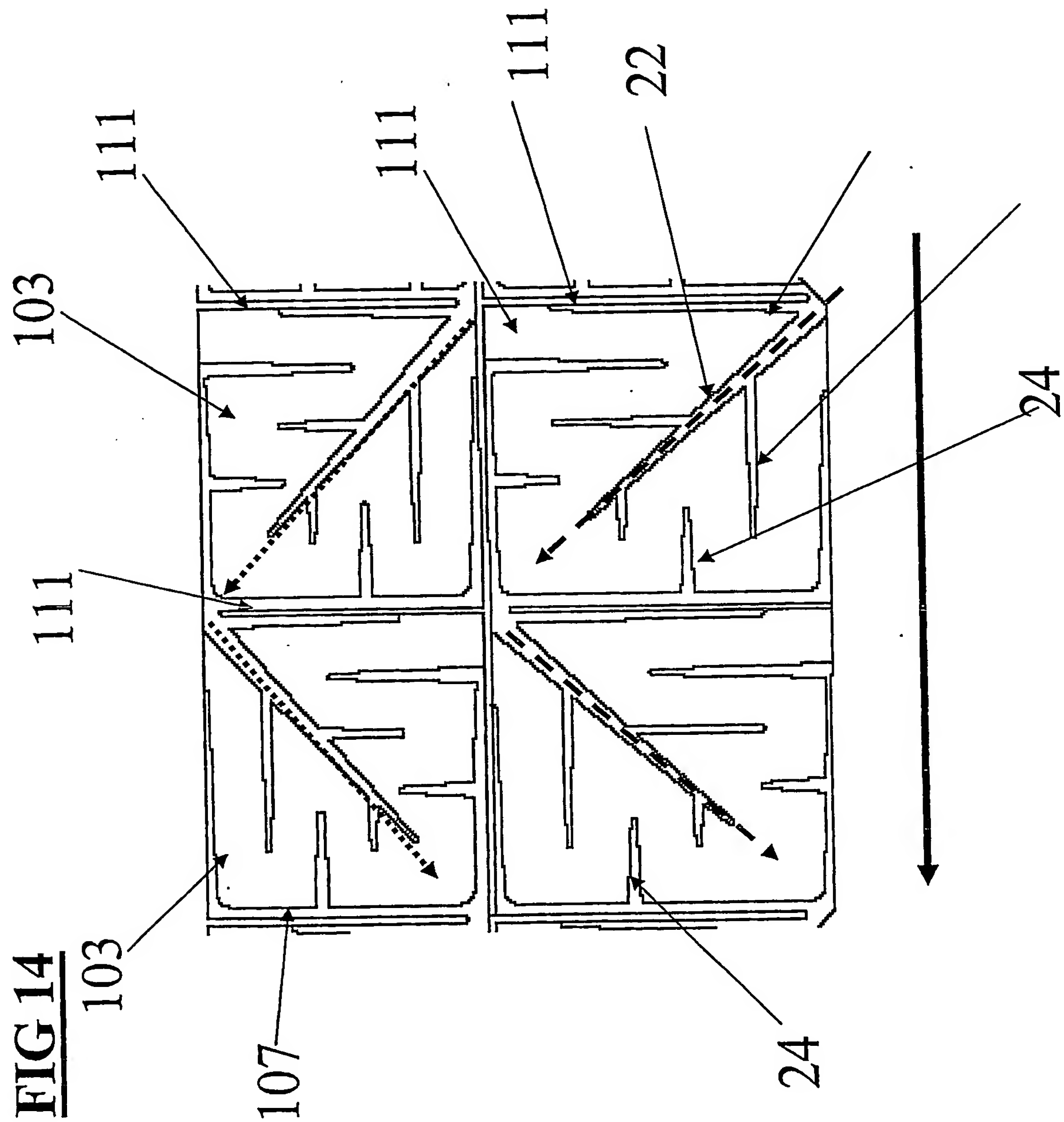
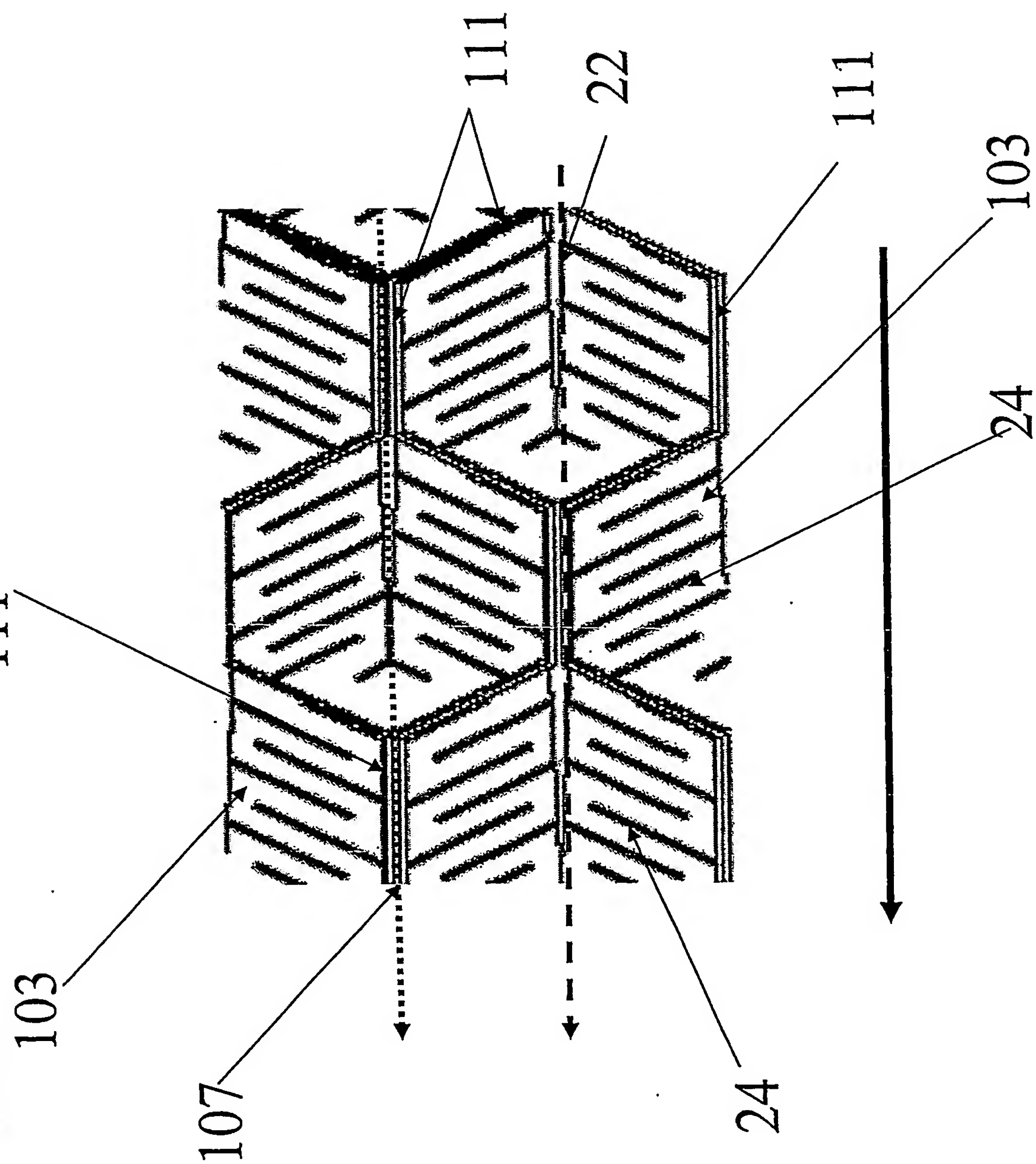


FIG 14

FIG 15



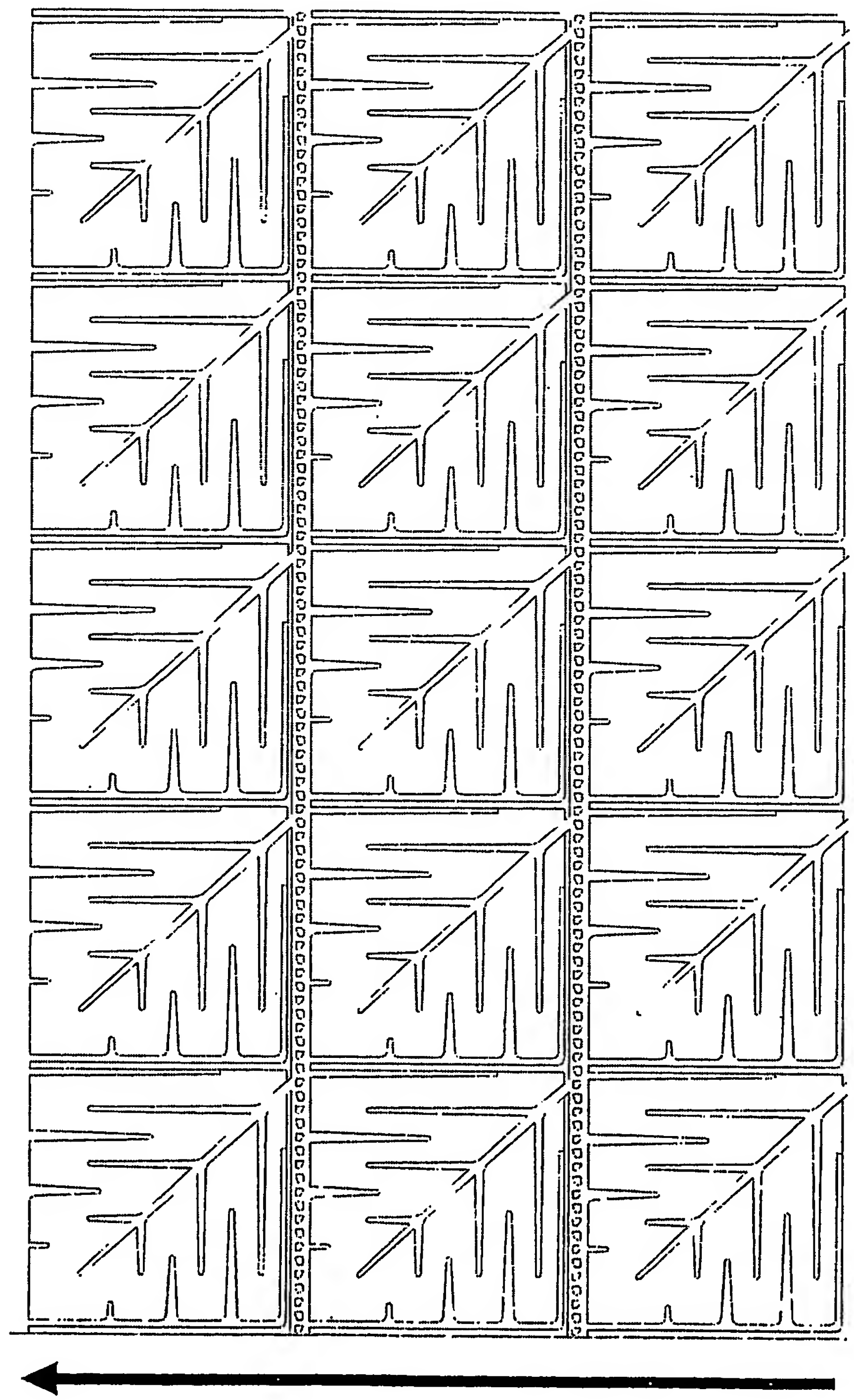


FIG 16